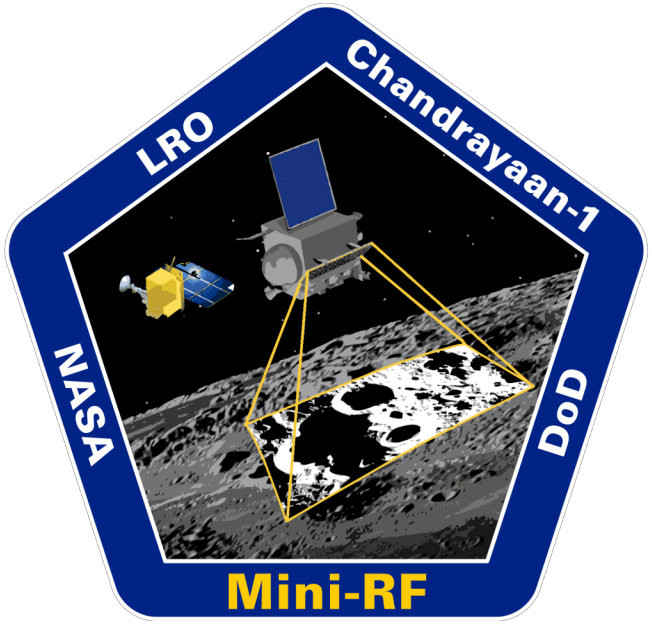
Mini-SAR

Initial Results from Calibration, Mapping, and Analysis



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NASA Lunar Science Forum

21 July, 2009

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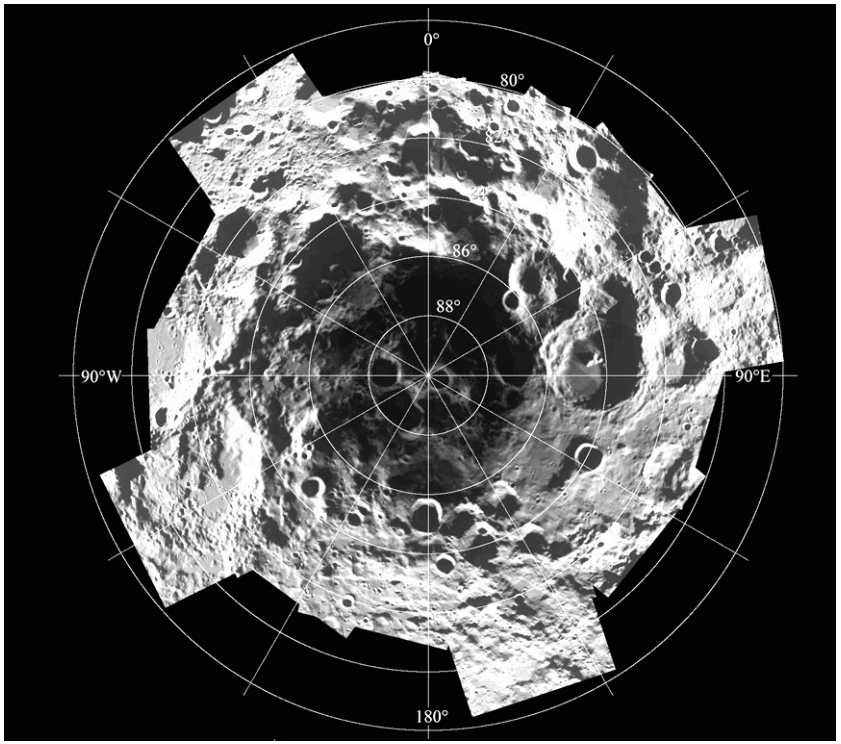
Experiment Objectives

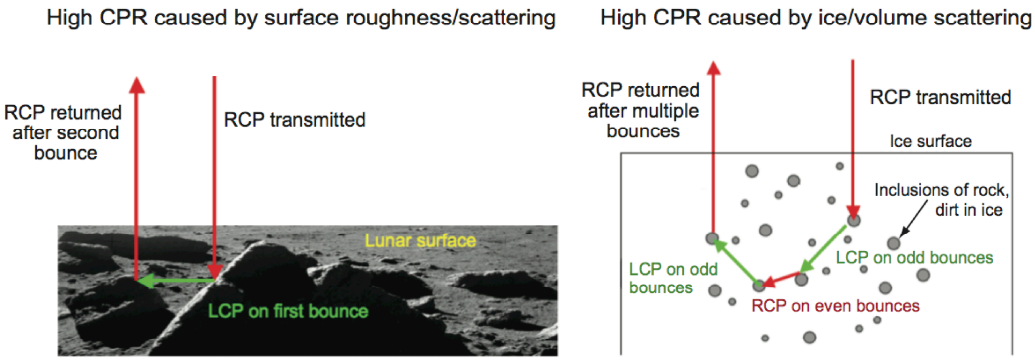
- Map the deposits of both poles of the Moon (> 80° lat.) at optimum viewing angles (~40°) to characterize permanently dark areas and definitively determine their RF backscatter properties using both SAR and scatterometry
- Complete the global map of the Moon by mapping dark regions in lunar polar areas
- Characterize the physical nature of the polar regolith and surface
- SAR mapping of other targets of opportunity as possible

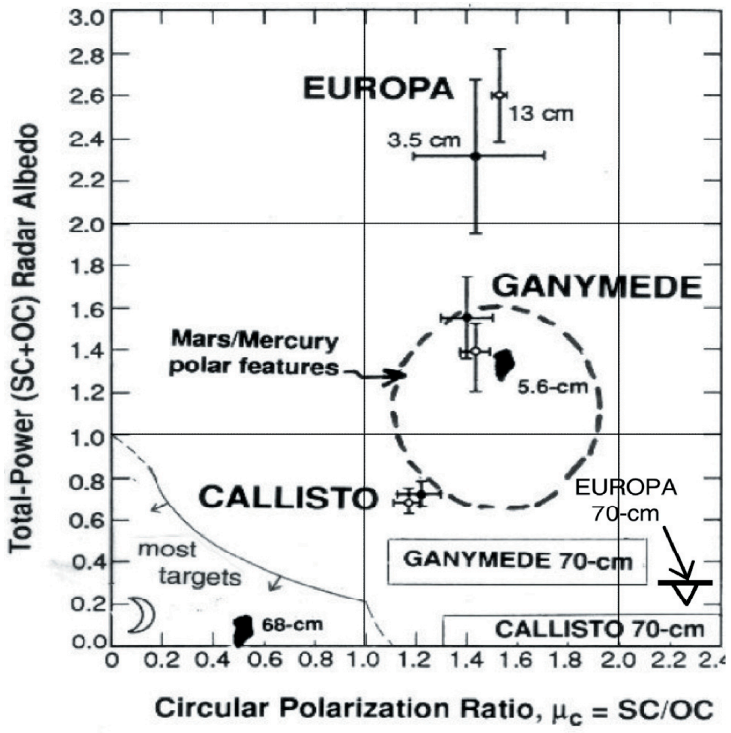


Moon South Pole
Clementine 750 nm base map

Circular Polarization Ratio (CPR)

- Ratio of received power in both right and left senses
- Normal rocky planet surfaces = polarization inversion (receive opposite sense from that transmitted)
- "Same sense" received indicates something unusual:
  - double- or even-multiple-bounce reflections
  - Volume scattering from RF-transparent material
- High CPR (enhanced "same sense" reception) is common for fresh, rough (at wavelength scale) targets and water ice





Does Ice Exist On The Moon?

Clementine

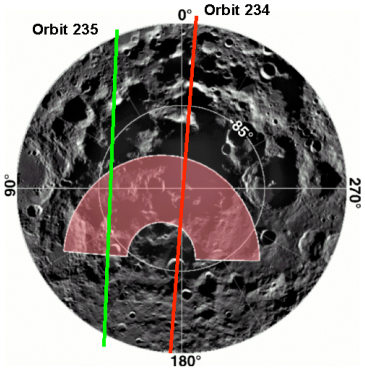
- On one orbit (234) found evidence for high same-sense backscatter (high CPR; CBOE?) over dark areas near poles
- Other orbits (e.g., 235; over sunlit areas) show no enhancement

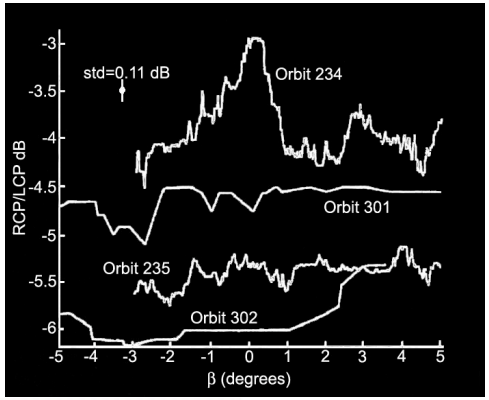
Lunar Prospector

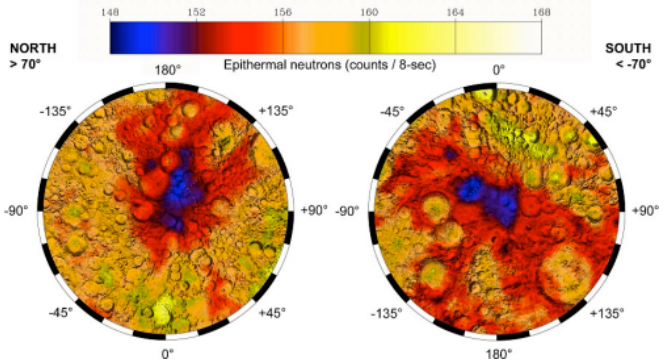
- Neutron spectrometer detects “excess” hydrogen (~2-3x global average), but not phase state
- Enhanced H_2 over poles; consistent with ~1-2 % ice or excess retained solar wind
- No H_2 signal in fast neutrons; upper ~10 cm of surface desiccated

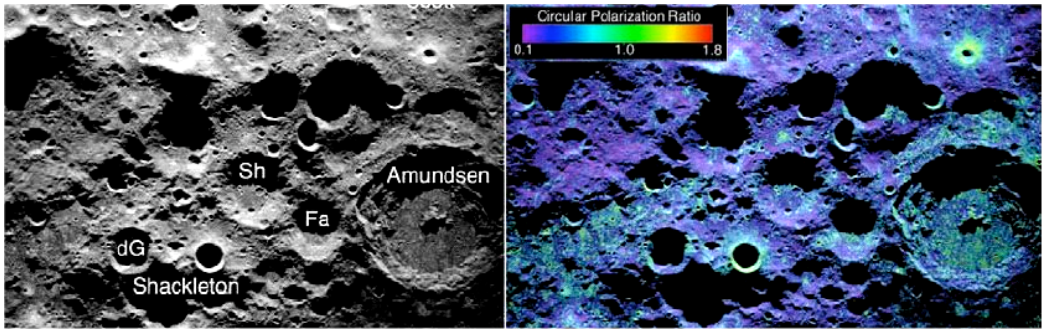
Earth-based radar

- Patchy, high CPR found in both sunlight and polar darkness
- All surface roughness or two different scattering mechanisms?









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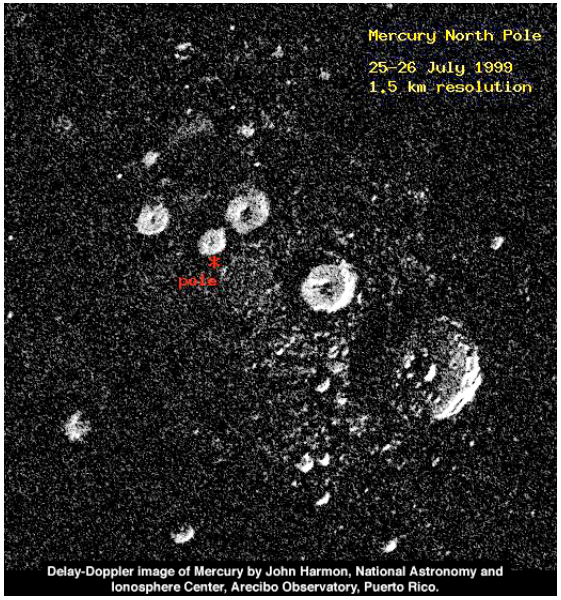
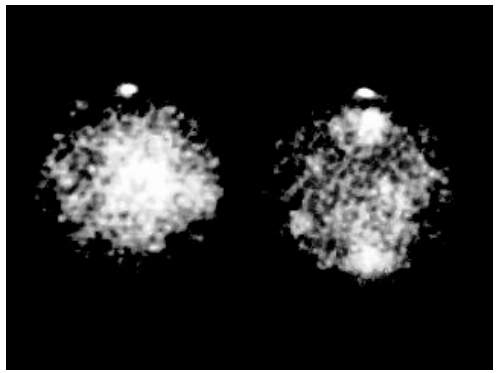
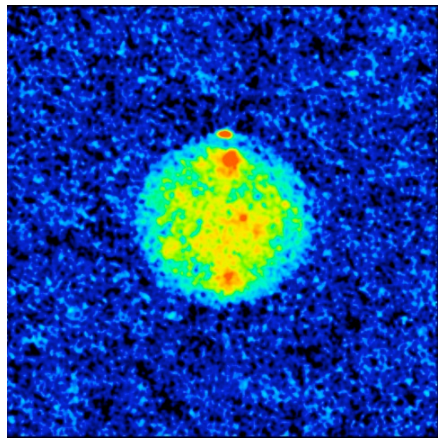
What does high CPR mean?

- Is high CPR diagnostic of surface roughness or composition?
- Mercury shows high CPR within polar crater floors (Harmon et al., 2000)
- Mercury also shows high CPR areas at mid-latitudes (Muhleman, 1991)
- On Mercury, it is accepted that high CPR may have different causes, depending on local geological circumstances
- High CPR on the Moon may likewise have multiple causes





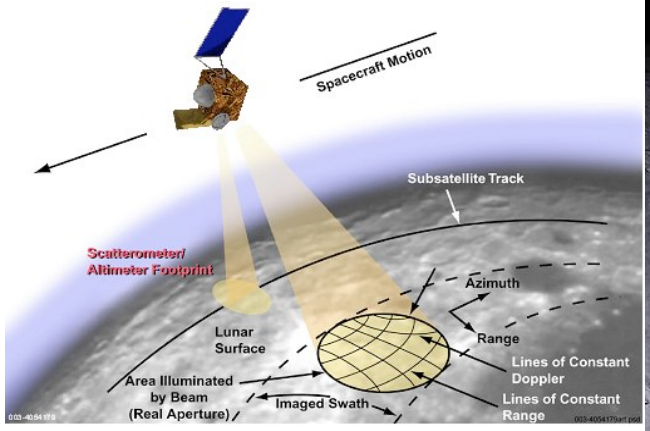


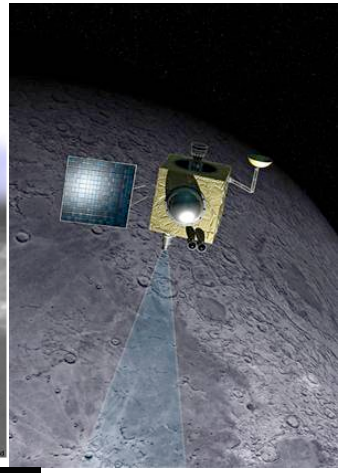
Mini-SAR

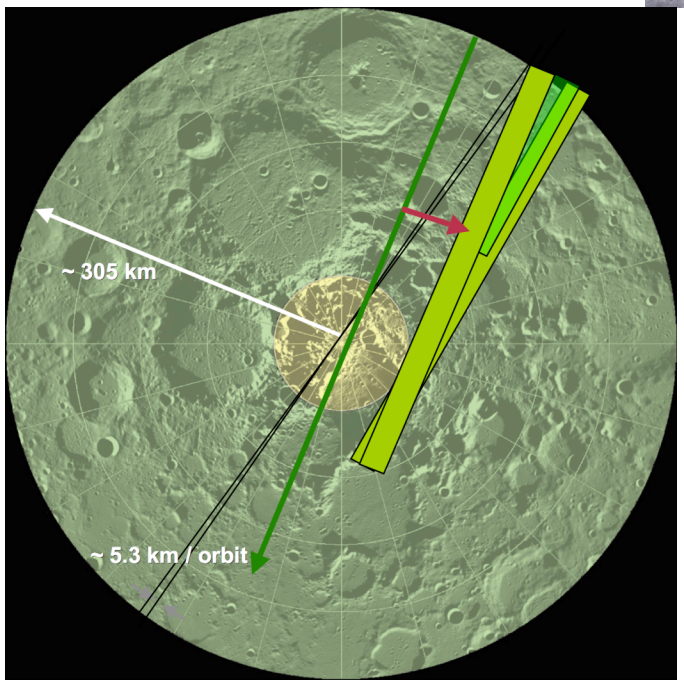
Imaging Radar on the Chandrayaan-1

- Mini-SAR is an S-band (13 cm) imaging radar with hybrid polarity architecture
- Map both polar regions at 75 m/pixel
- Transmit LCP, receive ***H*** and ***V*** linear, coherently
- Use Stokes parameters and derived "daughter" products to describe backscattered field
- Map locations and extent of anomalous radar reflectivity
- See polar dark areas (not visible from Earth)
- Cross-correlate with other data sets (topography, thermal, neutron)

- LRO version (Mini-RF) has two bands (λ=13 and 5 cm), high-resolution zoom mode (15 m/pixel)







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Mini-SAR Calibration Activities

Pre-flight laboratory measurements; antenna pattern mapped

Translunar calibration (*cancelled*)

Arecibo radiotelescope calibration (31 Jan. 2009)

- Ground transmit pure RCP signal to C-1
- Map Rx channel gain/separation

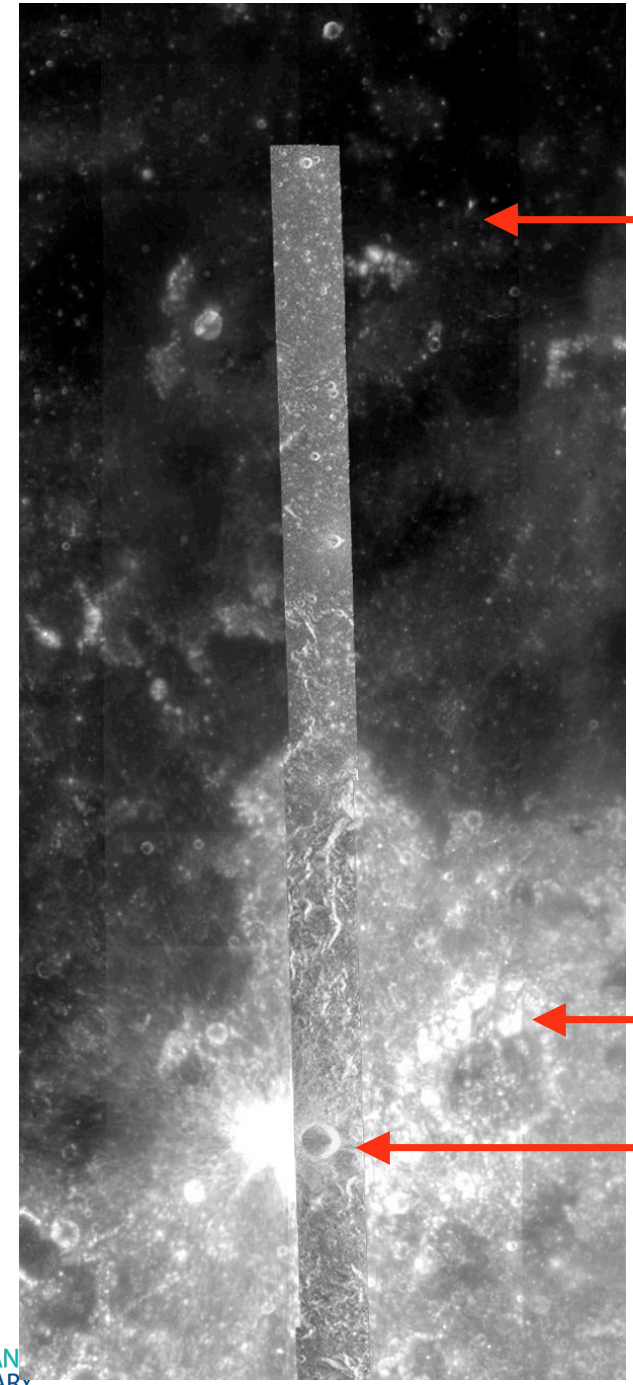
Greenbank radiotelescope cal (27 Feb. 2009)

- C-1 Tx to Earth
- Measure Tx signal
- Articulate spacecraft to map antenna pattern

Sample data and calibration data takes

- SAR take 17 Nov. 2008 - both poles (first data)
- SAR take 7 Jan. 2009 - both poles, including steep incidence pass
- Scatterometry take 18 Jan. 2009 - 11° to 18° N along 54° E
- SAR take 20 Jan. 2009 -- Equatorial (6°S to 6°N) along 32° E

Work to fully calibrate the Mini-SAR instrument is ongoing



Mare Tranquillitatis

MSR Equatorial Calibration, 20 Jan. 2009

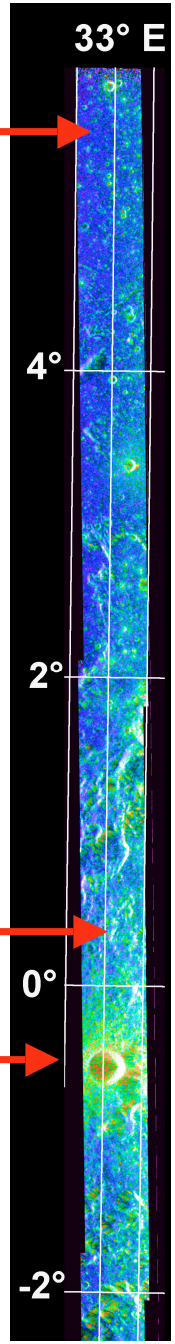
Collect SAR strip such that viewing geometry matched that of Earth-based radar imaging

Data successfully gathered along longitude 33° E, from 6° S to 6° N latitude

Nectaris basin highlands

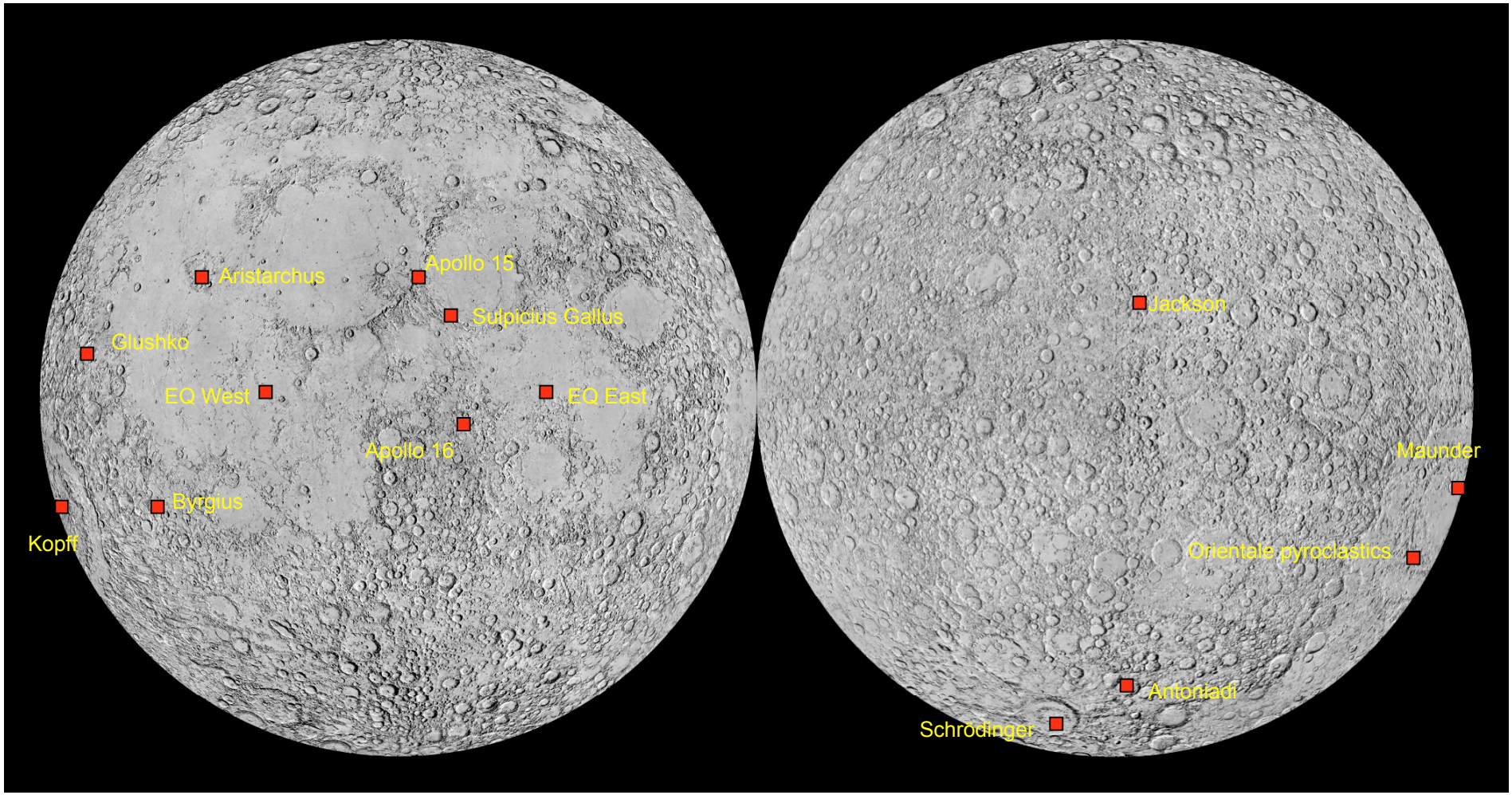
Censorinus A

CPR image

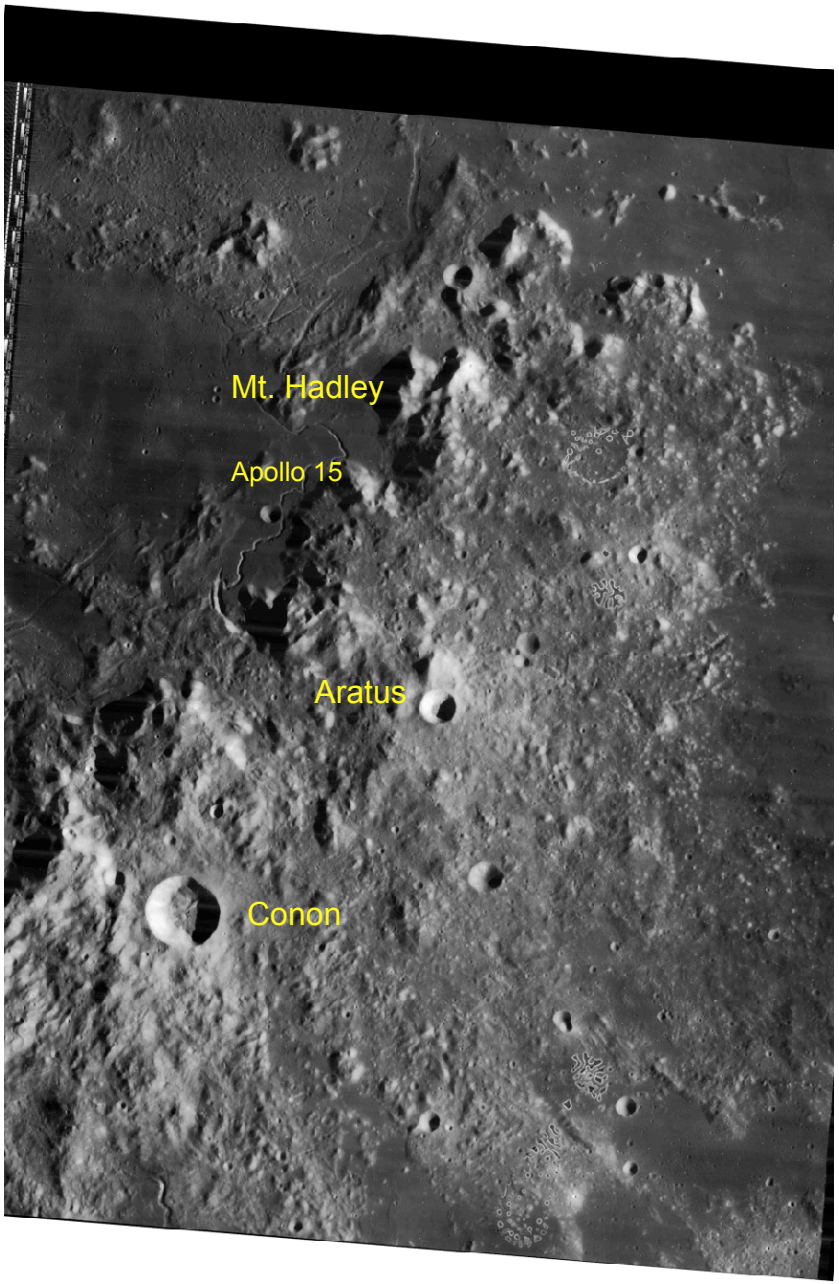


Mini-SAR strip on Clementine 750 nm base map

MSR non-polar targets



Apollo 15



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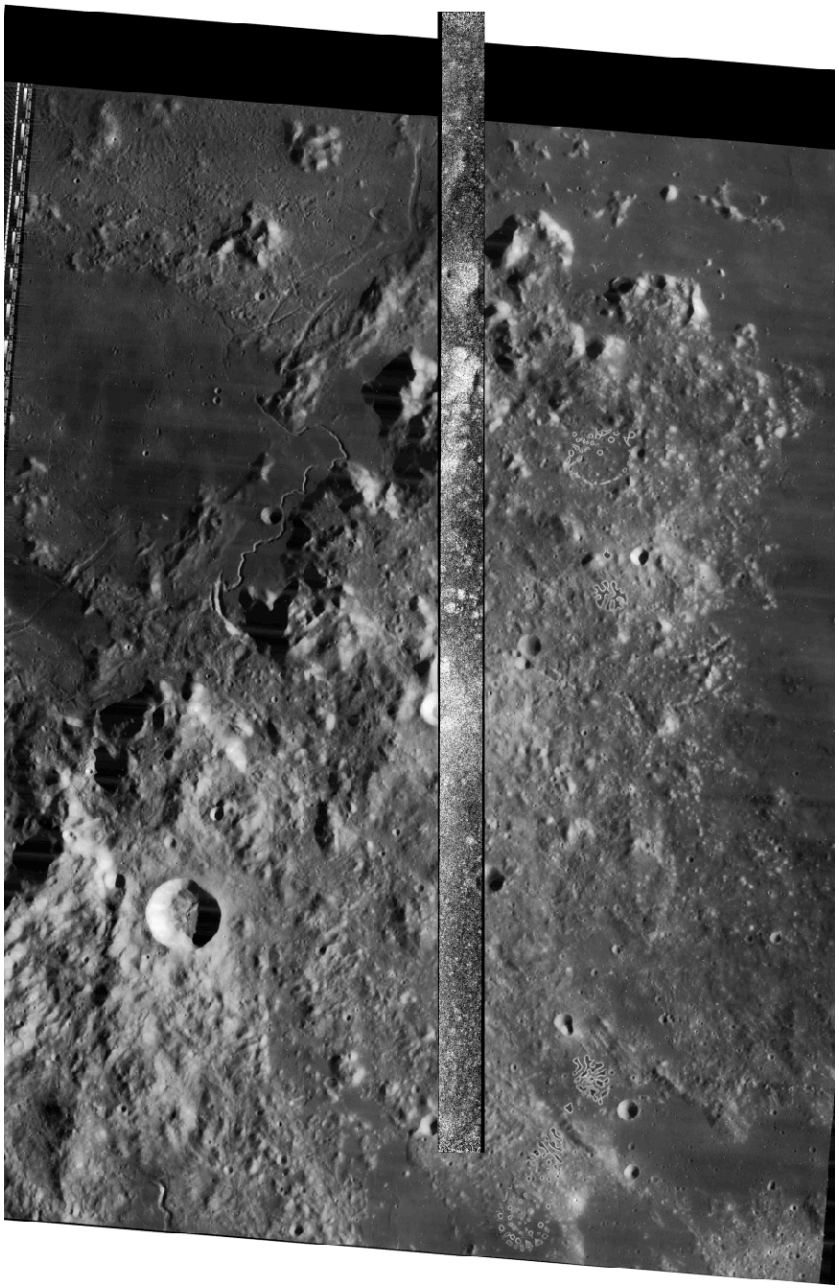
Apollo 15

Apollo 15



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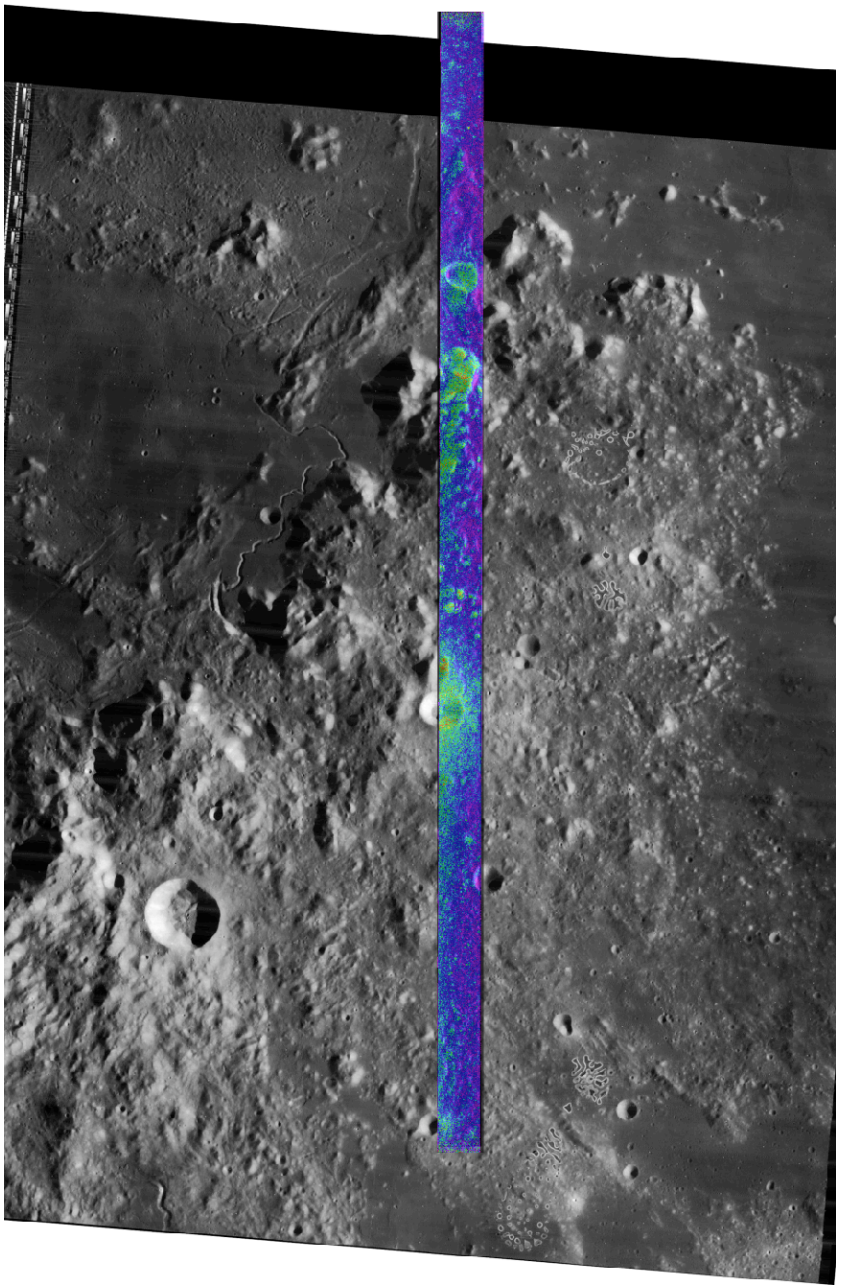
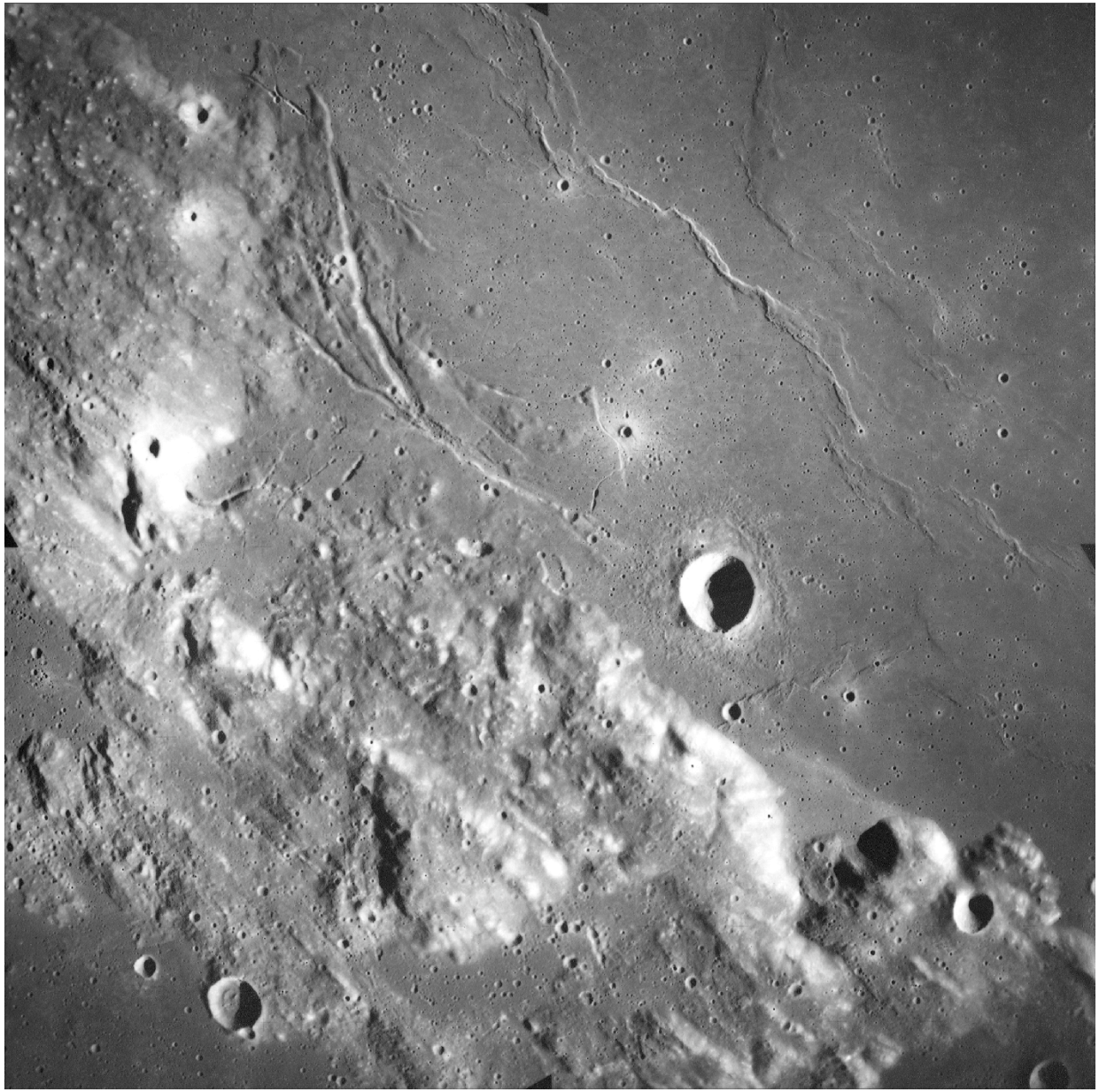


Sulpicius Gallus



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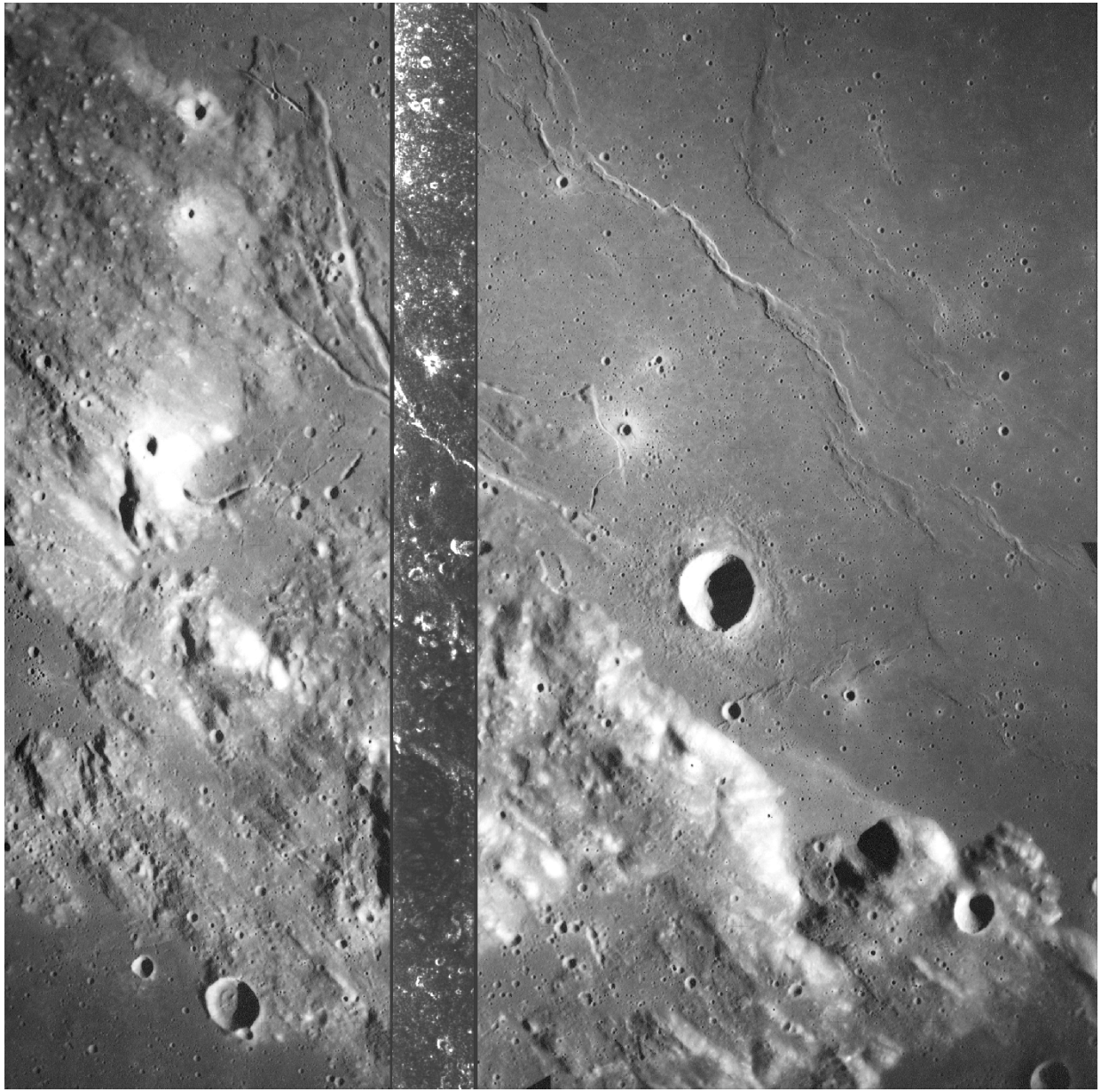

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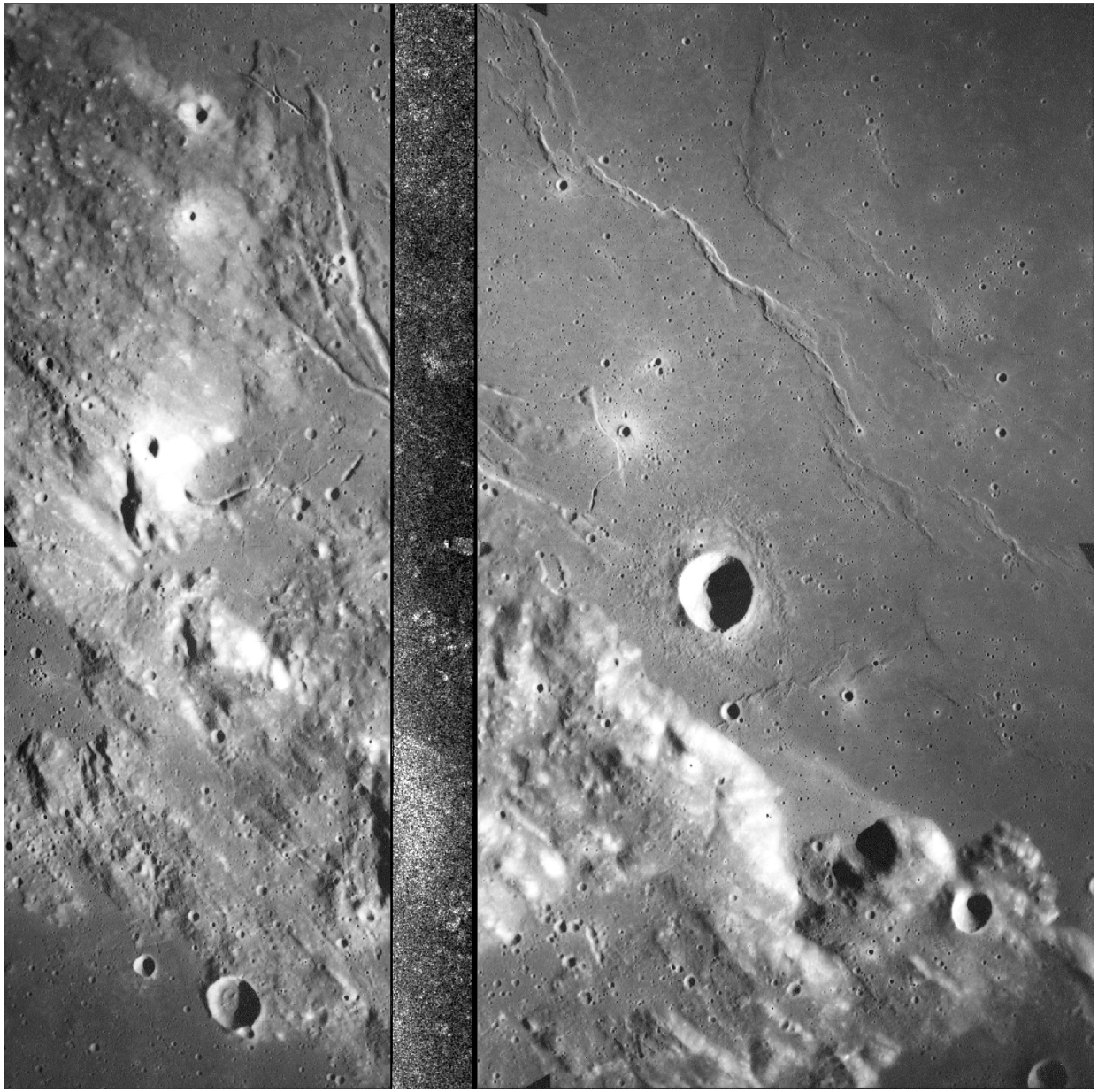

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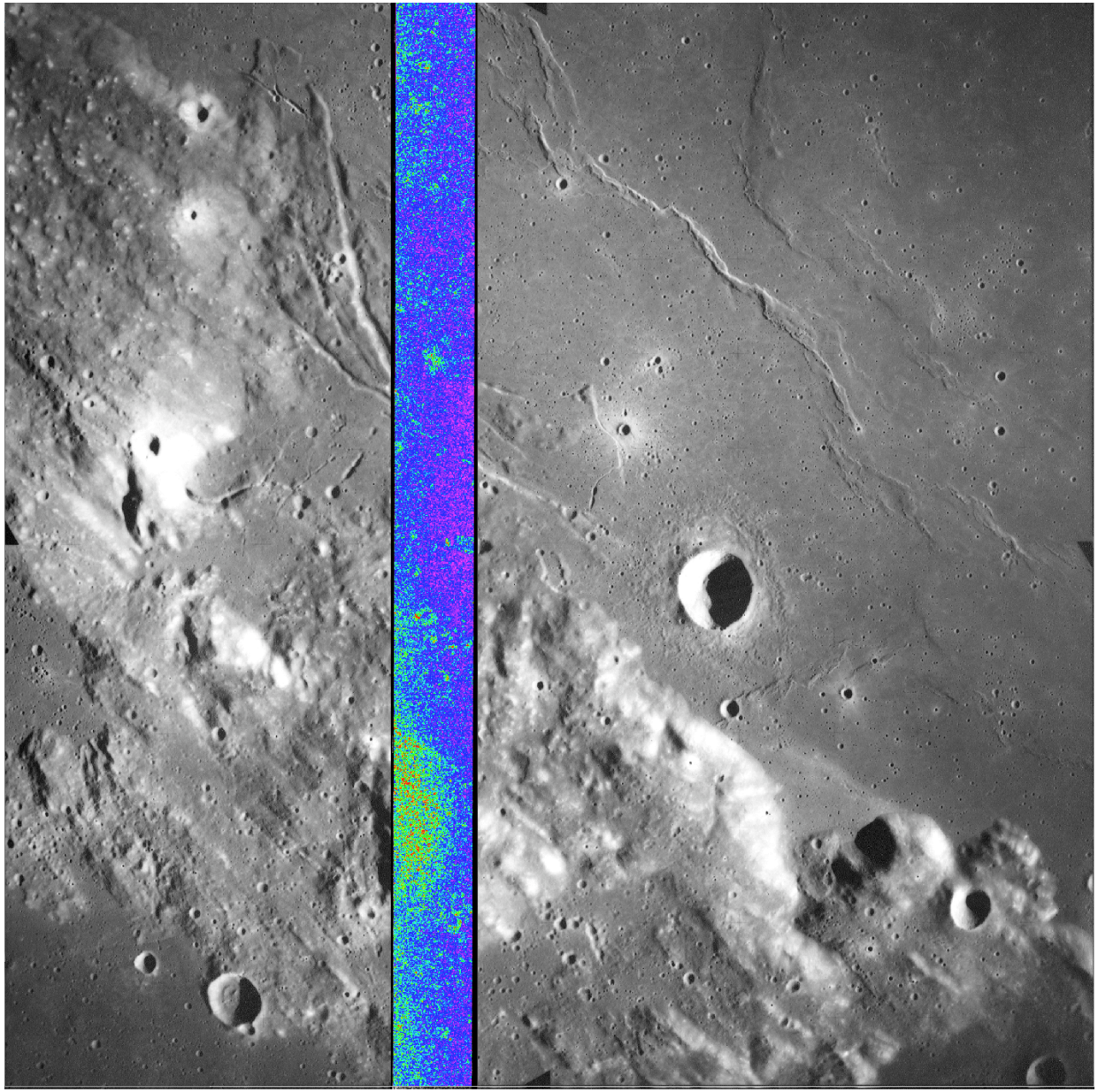
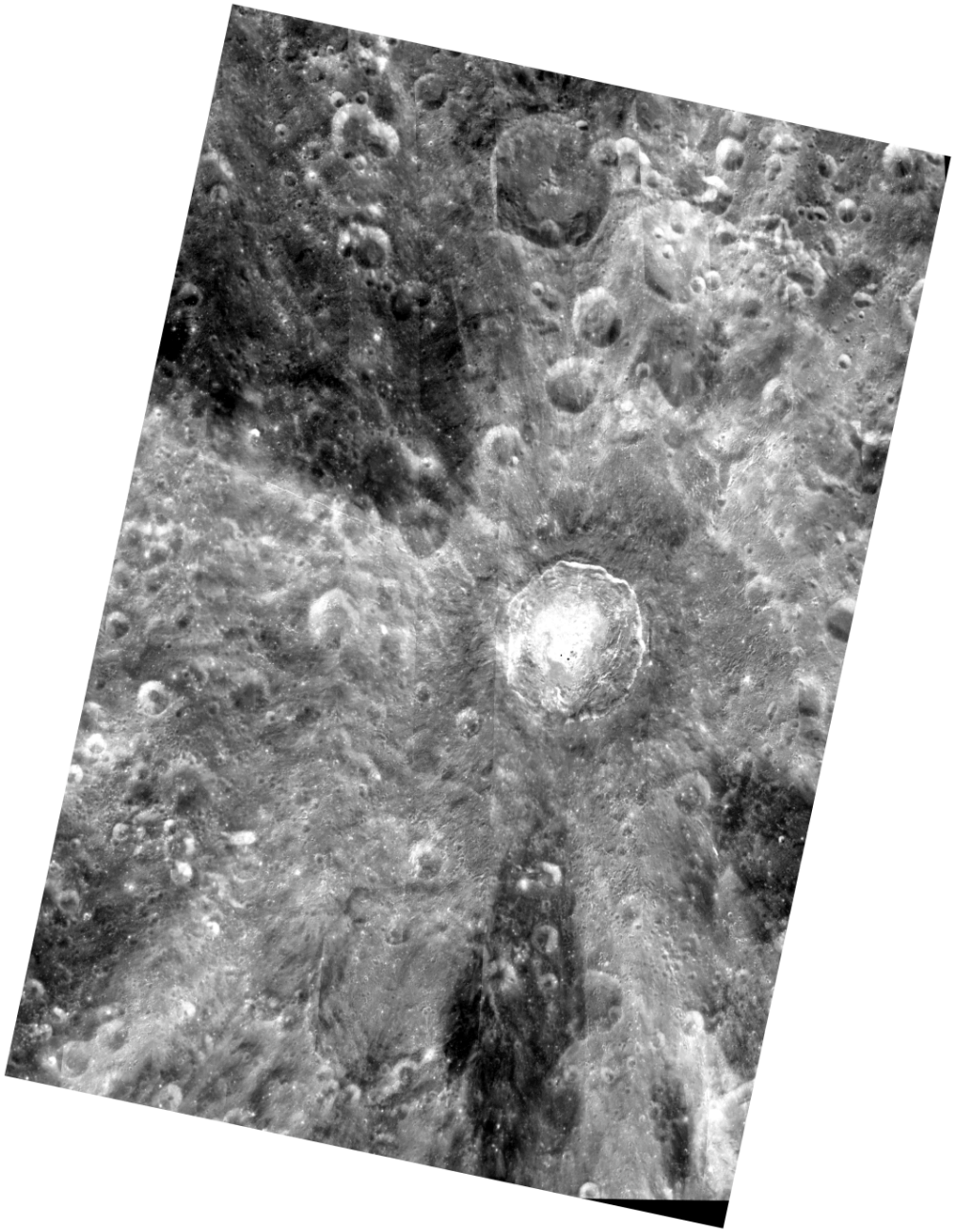


Jackson



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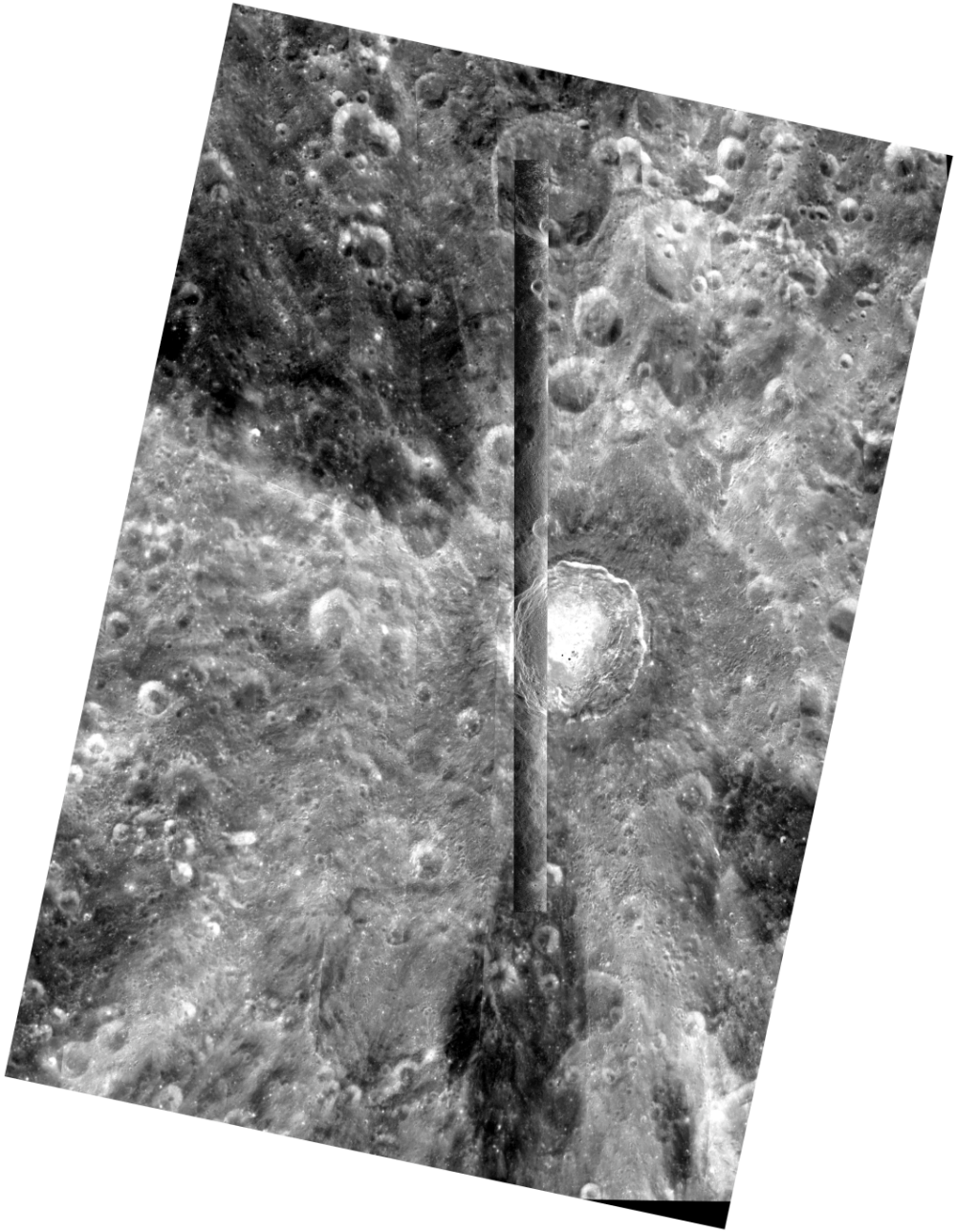

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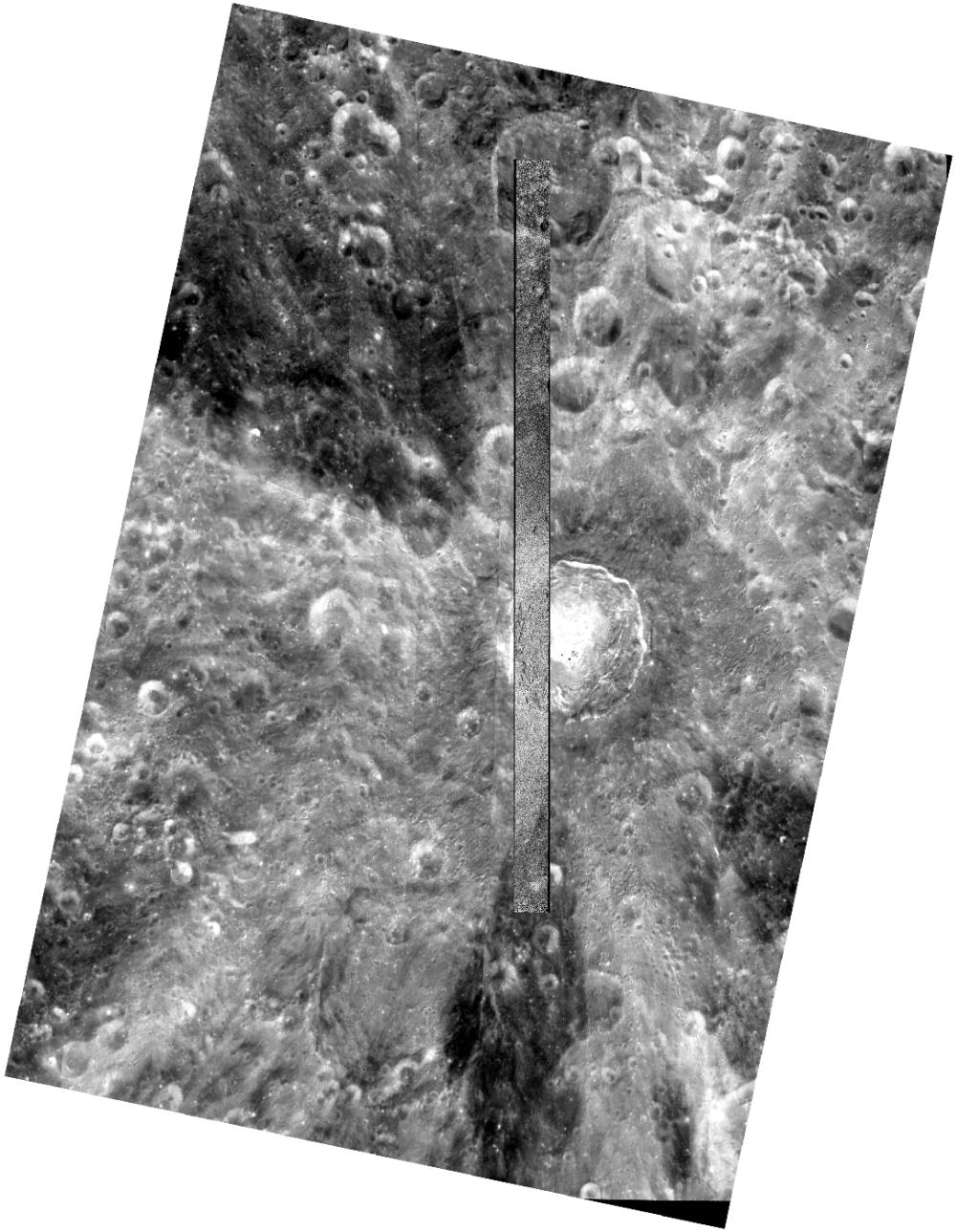

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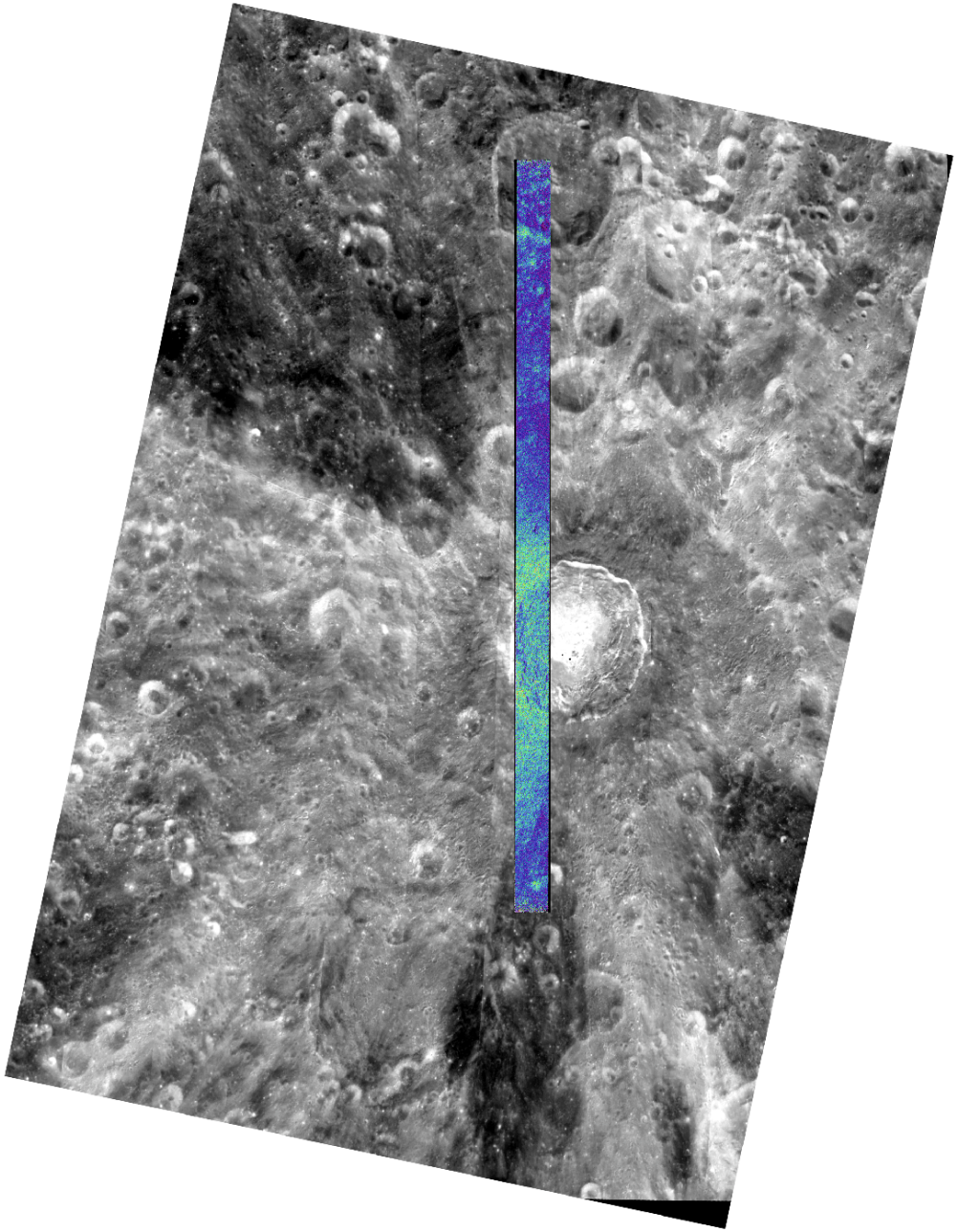
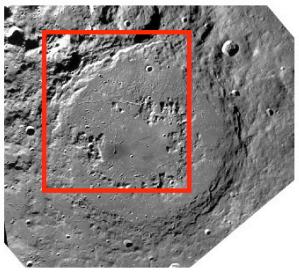


Schrödinger Basin

Lunar far side

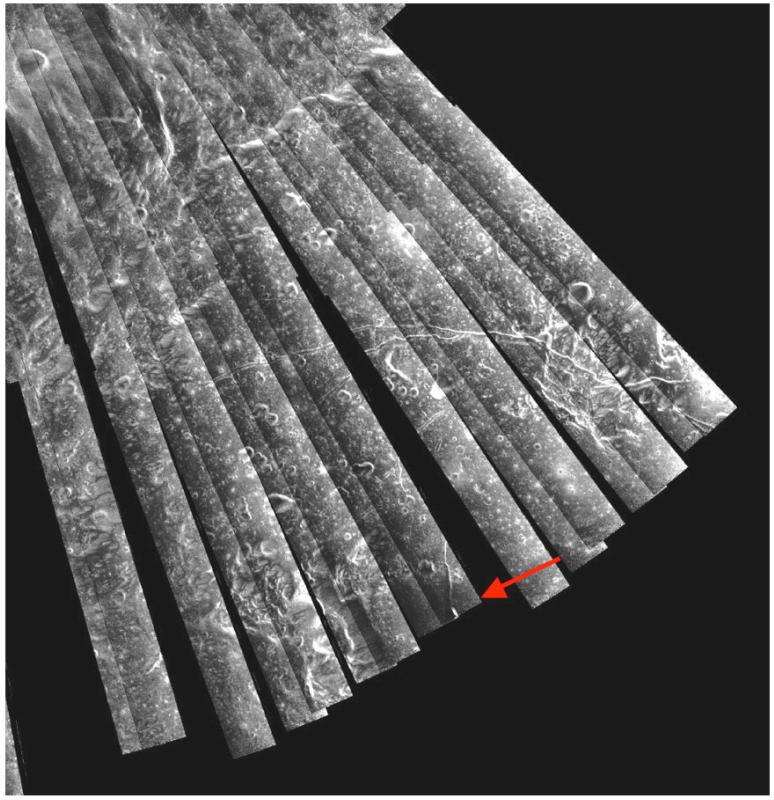
320 km diameter; Center 75° S, 132° E

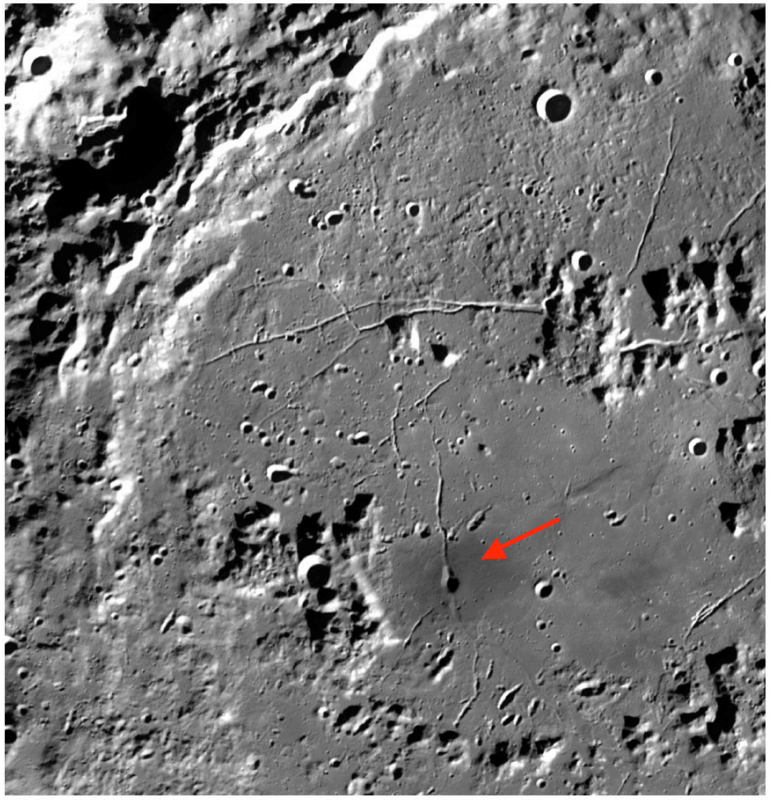


Mini-SAR images

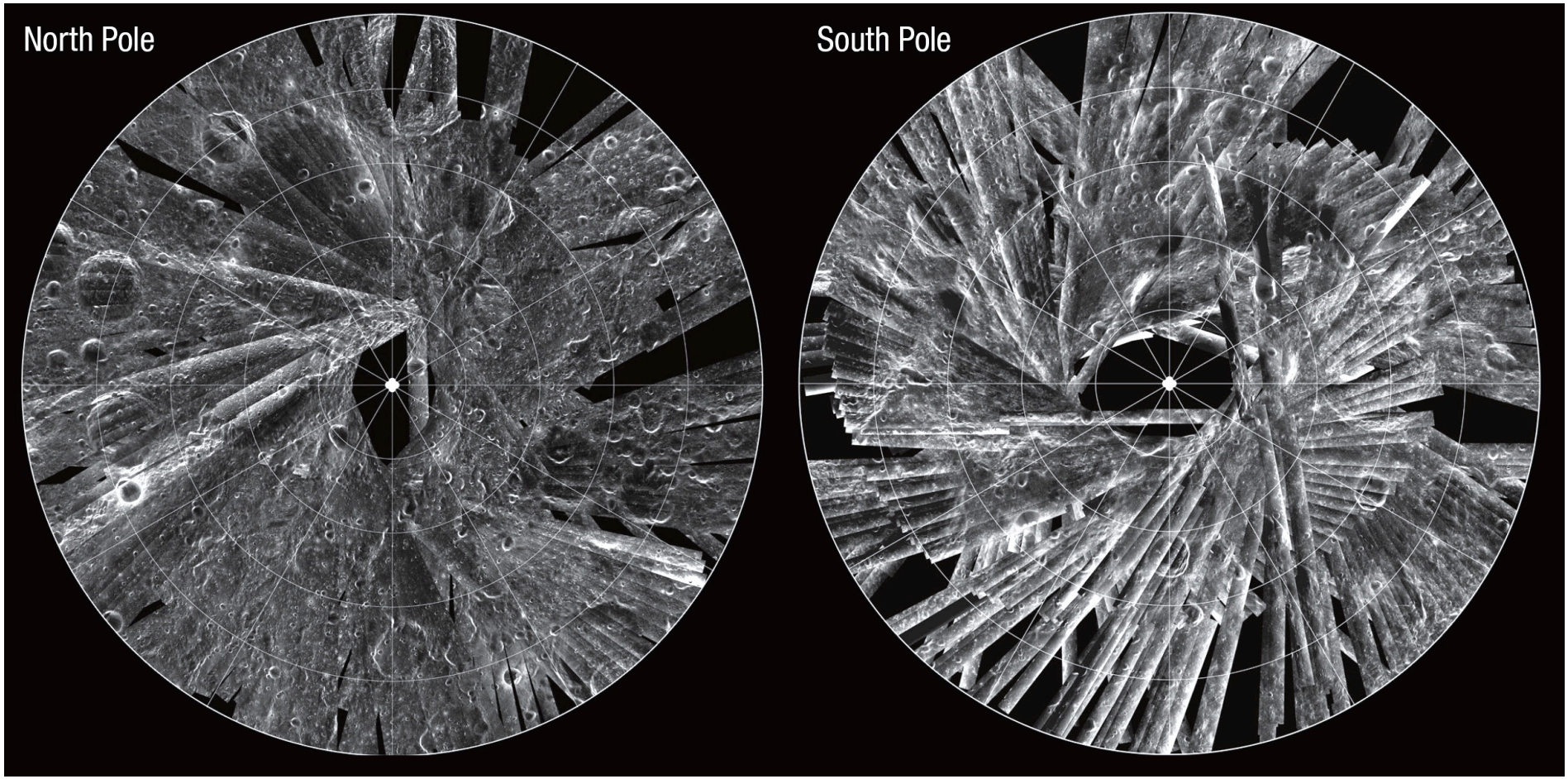
10 km

Clementine mosaics





MSR Coverage from First Mapping Cycle



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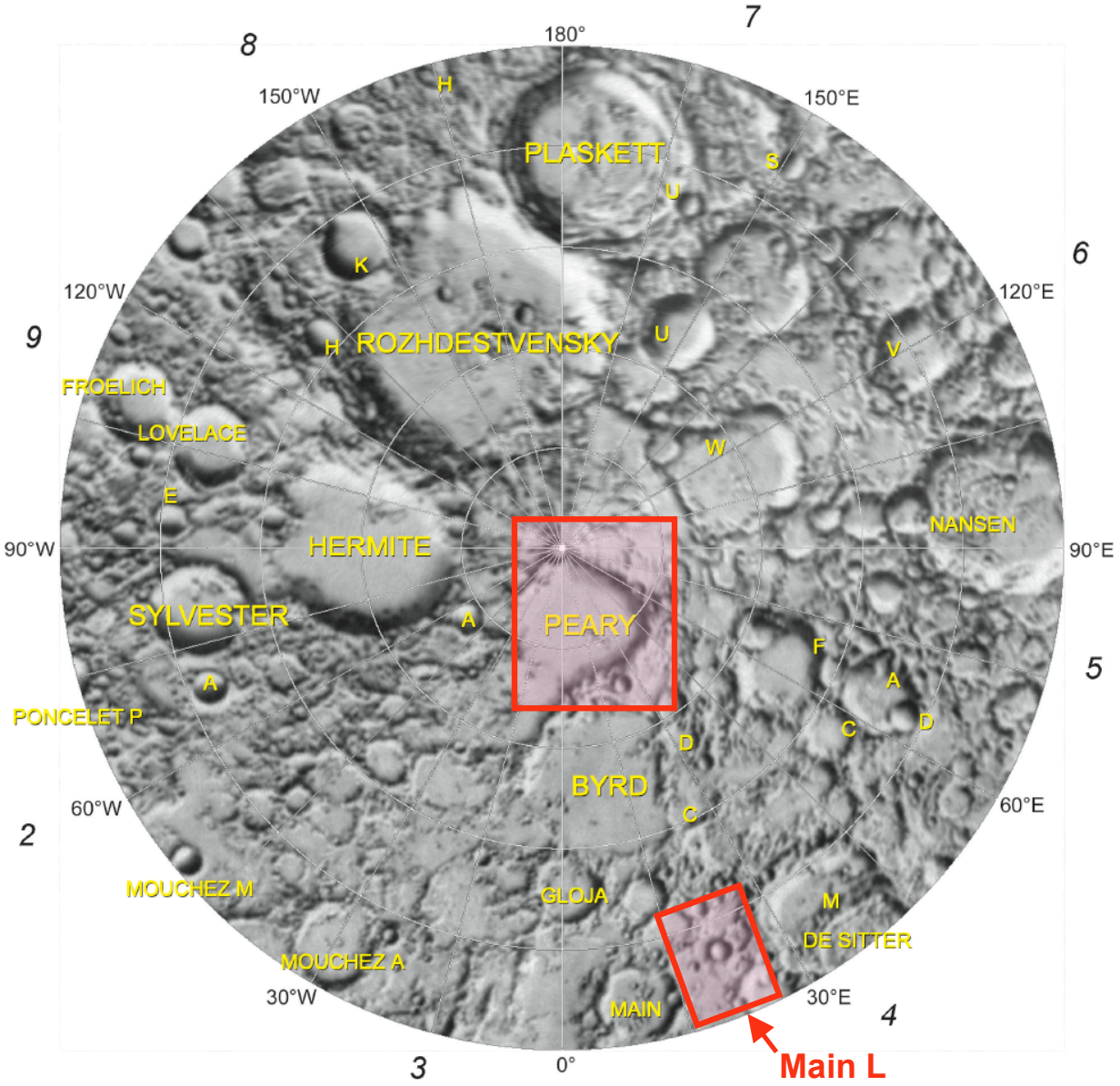
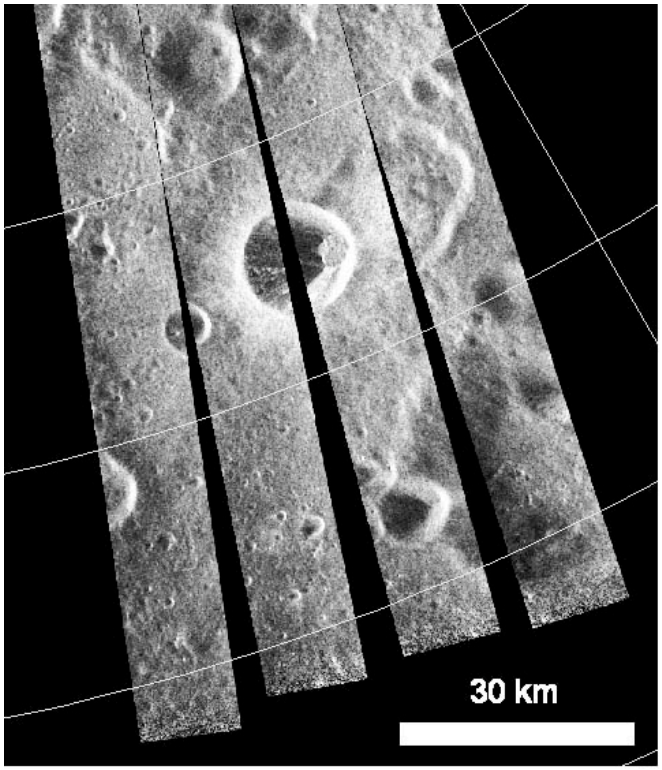
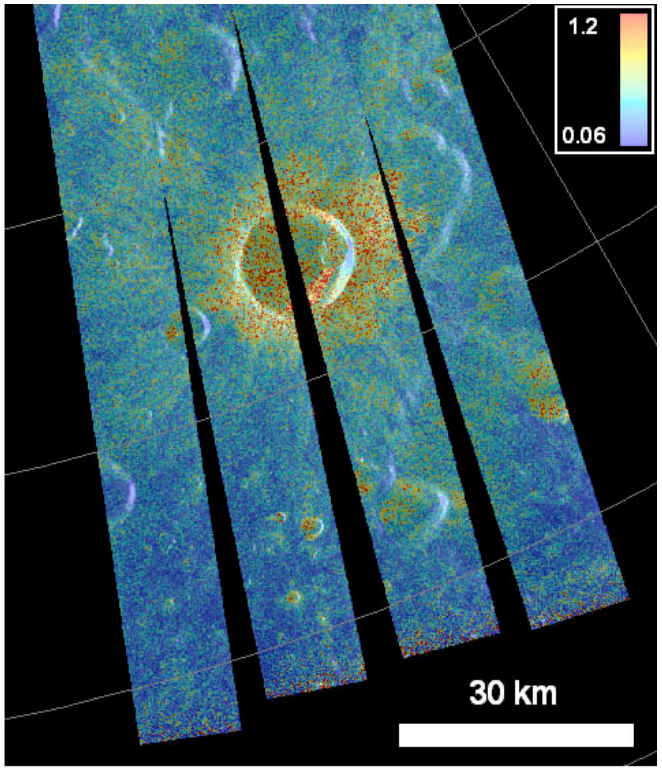
A Tale of Two Scatterers



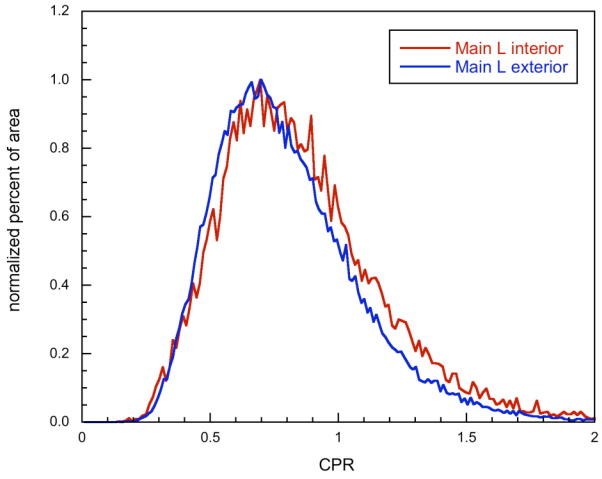




OS SAR image

Main L
14 km diameter
81.4° N, 22° E

CPR image



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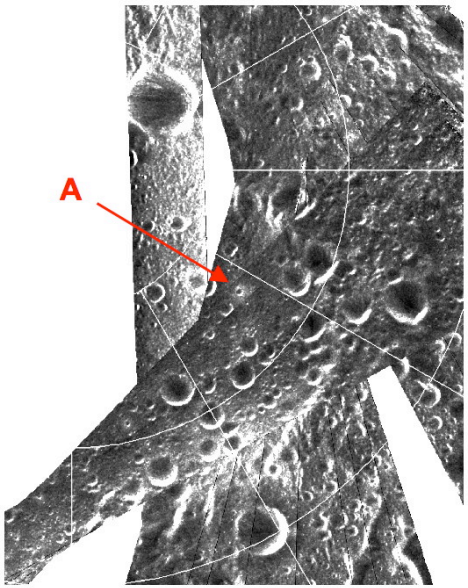
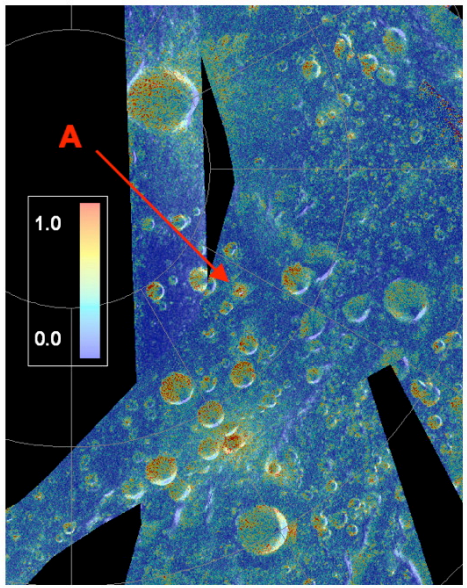
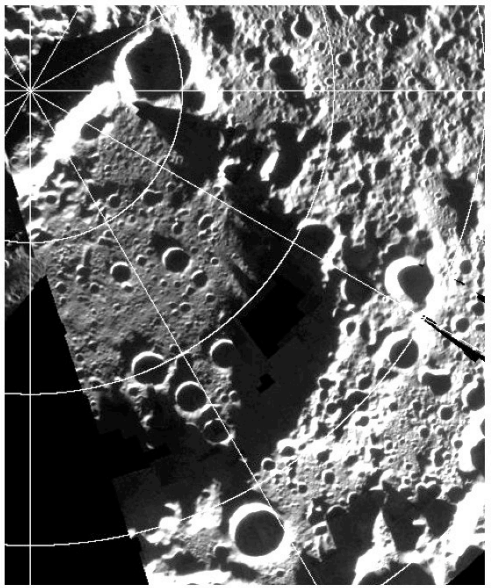




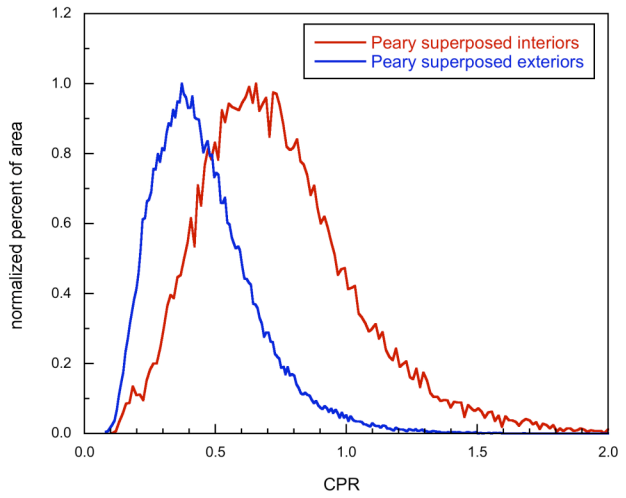


OS SAR mosaic

CPR mosaic

Clementine hires mosaic

Floor of Peary
73 km diameter
88.6° N, 33° E



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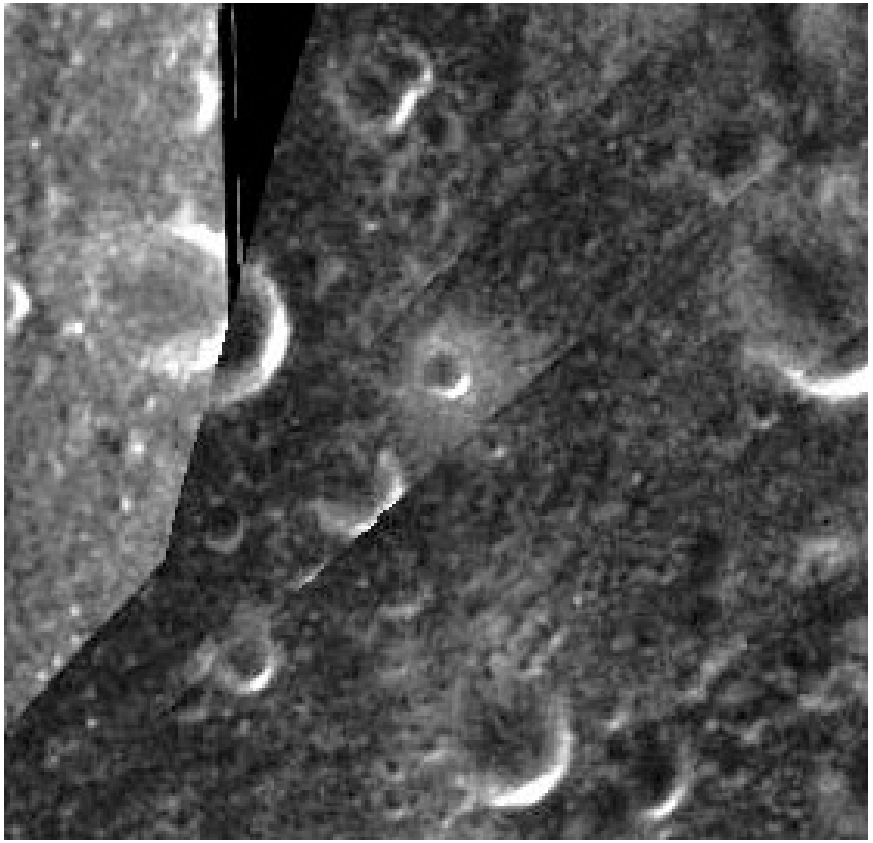
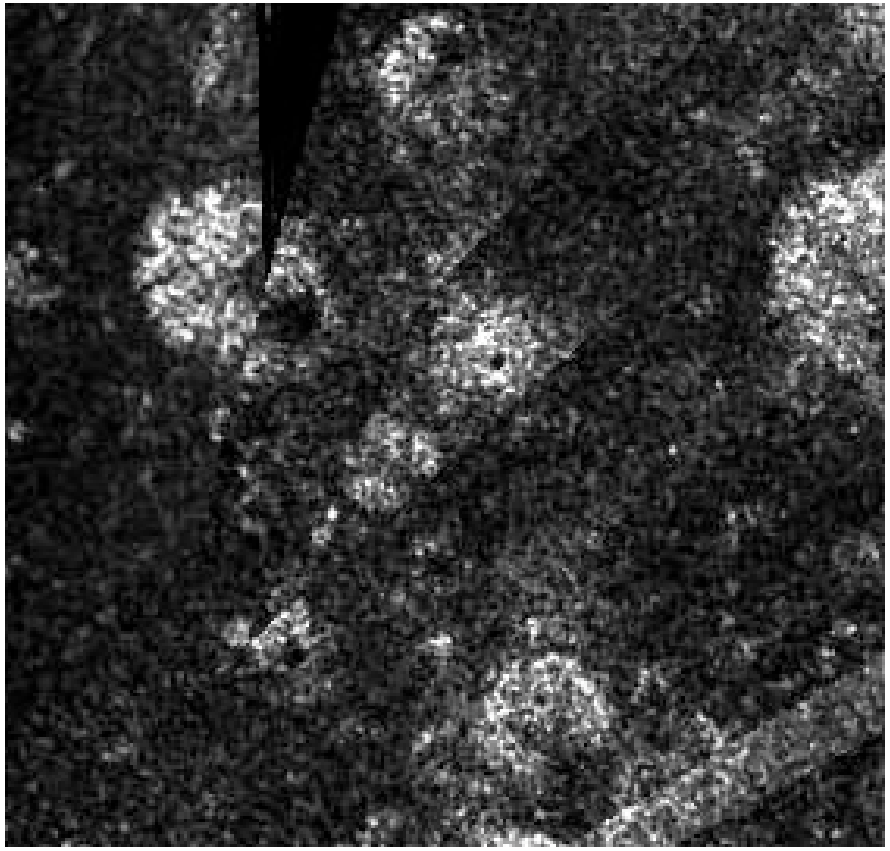
Close-up of Floor of Peary



OS SAR image



CPR SAR image

Summary

Mini-SAR is operational and is mapping the poles of the Moon

Calibration data has been obtained and SAR data is being reprocessed using this information

We have mapped about 95% of both polar areas; due to some operational issues, coverage is not contiguous

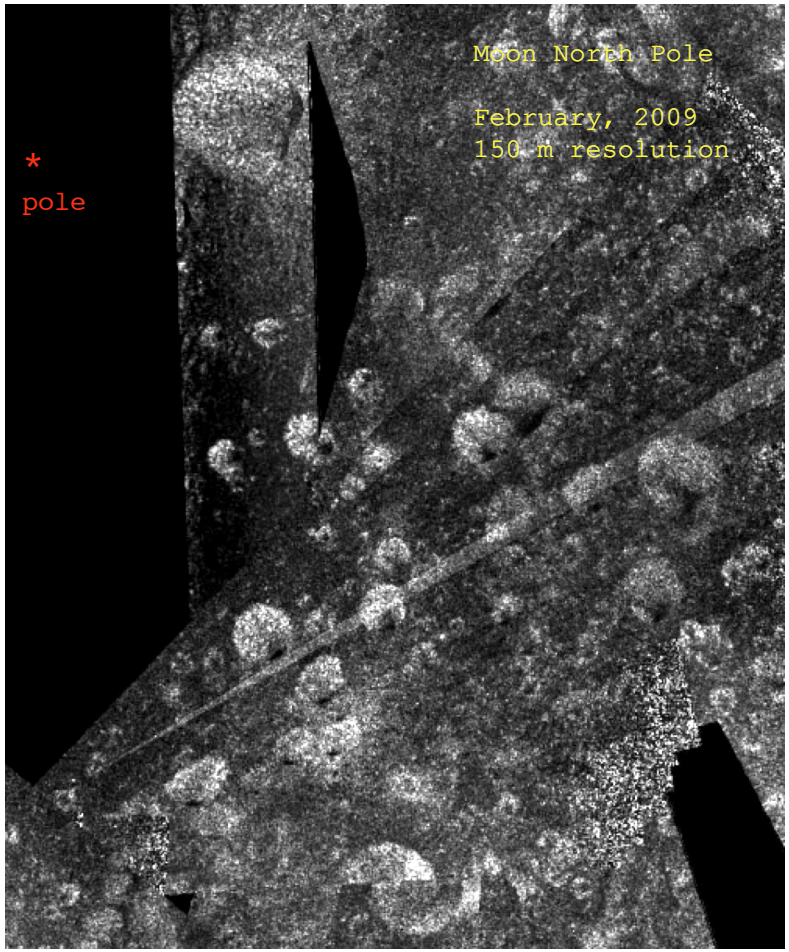
Areas of high CPR have been identified:

- Some high CPR is clearly associated with surface roughness (e.g., Main L ejecta blanket)
- Some deposits (e.g., near north pole on floor of Peary) show high CPR and are restricted to the *interior* of craters; these features are in permanent darkness. Cause under investigation

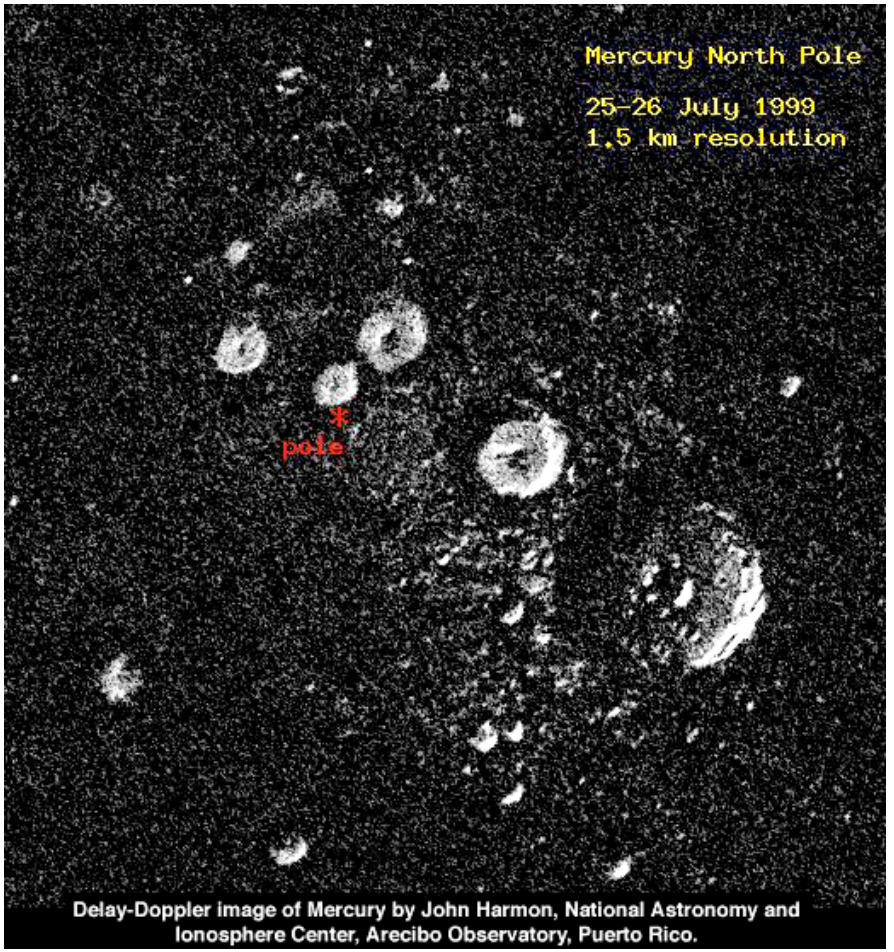
Future Work:

- Next mapping cycle mid-August to mid-October, 2009 (from 200 km orbit)
- Complete mapping of both poles in both look directions
- Fill-in polar (and other) gaps in coverage (SAR and scatterometry)
- Conduct Stokes analysis of polar deposit backscatter properties
- Compare and correlate with other data (e.g., topo, neutron, thermal)

High CPR at North Pole



Moon



Mercury